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ABSTRACT

Many studies have reported that college students often do not know the principle that liquids remain invariantly horizontal, and that this is more often true of women than of men. Two experiments were conducted to replicate sex effects on a water-level task while controlling for academic interests and background. The first experiment investigated the relationship between subjects' (N=250) college majors and water-level task performance. Twenty-five males and 25 females within each of five college majors (language arts, business, social sciences, natural sciences, engineering) completed a pencil-and-paper Piagetian water-level task in which they drew a line representing where the liquid would be in each of eight drawings of tilted bottles. Because college majors are confounded and vaguely defined, experiment 2 attempted to operationalize occupational preferences and interests by using an occupational inventory. Subjects (N=194) completed a briefer version of the water-level task. The results revealed that, although sex effects remained stable when previous academic experience was controlled for, significant differences between college majors for both sexes were found. Men in the sciences were found to perform most accurately and women in the arts to perform least accurately. Findings suggest that academic experiences may affect task performance within and between sexes, but cannot completely account for sex differences. (NB)

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WATER RUNNING-UP-HILL: A CLOSER LOOK AT SEX DIFFERENCES IN PERCEIVING THE INVARIANT HORIZONTALITY OF LIQUIDS

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Piaget and Inhelder (1956) indicated that by the age of 11 years children learn the concept that liquids remain invariantly horizontal. Piaget theorized that the understanding of this physical principle was a function the development of Euclidean spatial concepts during concrete operations. Knowledge of the physical principles that govern the behavior of liquids have been demonstrated to predict accurate water-level task performance (Thomas & Jamison, 1975; Barsky & Lachman, 1986). Numerous studies over the past two decades have reported that many college students do not know the principle that liquids remain invariantly horizontal, and that this is more often true of women than men (Thomas, Jamison & Hummel, 1973; Halpern, 1986). While studies utilize college students as subjects, no [illegible] the literature has reported controlling for educa[illegible] history.

Two experiments were conducted to replicate sex effects on a water level task while controlling for academic interests and background. The first experiment investigated the relationship between subjects' college majors and water-level task performance. Because college majors are confounded and vaguely defined, experiment 2 attempted to operationalize occupational preferences and interests by employing an occupational inventory.

Experiment 1

Method

Two hundred and fifty undergraduates were grouped by sex and college major: language arts, business, social scienc[illegible] natural sciences and engineering. Twenty-five males and 25 females within each college major were recruited from introductory psychology courses.

Subjects received a paper-pencil Piagetian water-level task (Wittig and Allen, 1984). Subjects were instructed to draw a line representing where the liquid would be in each of eight drawings of tilted bottles. Pass/fail scores were calculated using 6° off of the horizontal axis as the criteria for significant error and judging 5 of 8 responses correct (63%) as a pass (Wittig and Allen, 1984).

Subjects also responded to questions addressing their understanding of the concept of horizontality.

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Results

Table 1 presents the numbers of subjects passing and failing the task as function of sex and college major. A significant difference was indicated between sexes with men performing more accurately than women within each college major (X^2 = 26.6, p <.001). There was also a significant effect of college major on water-level task performance (X^2 = 16.9, p <.002), science majors performed more accurately than arts majors. There was no sex by college major interaction indicated.

Insert table 1 about here

Responses to questions pertaining to the knowledge of physical information about liquids indicated that significantly more men than women articulated the principle that liquids remain invariantly horizontal (X^2 = 10.5, p <.001). There was again a significant effect of college major, science majors articulated the principle significantly more often than arts majors (X^2 = 5.1, p <.05). There was no indication of a sex by college major interaction in reporting knowledge of physical information.

Experiment 2

Method

A second sample of 97 male and 97 female undergraduates was administered a briefer version of the water-level task described above, consisting of four test stimuli. Subjects were grouped by their scores into accurate performers, defined by producing at least 3 of 4 correct responses, and inaccurate performers, producing 3 or less correct responses. Each group completed the Self Directed Search (SDS), a career interest inventory reflecting various skills and preferences related to specific occupational typologies (Holland, 1985). Scores consist of the sum of items that subjects indicate as being true for their interests and skills. The six scales are: Realistic interests reflect manual skills such as carpentry and mechanics; Investigative items reflect scientific interests such as engineering and physics; Artistic interests pertain to both language and fine arts; Social interests involve interacting with individuals or groups of people; Enterprising interests involve managerial and organization skills; and Conventional preferences are reflective of accounting and clerical skills (Holland; 1985).

Results

Table 2 presents the number of subjects performing accurately and inaccurately on the task as a function of subject sex. The sex effect was replicated in this sample, with men performing more accurately (X^2 = 21.3, p <.001), and knowing the principle of horizontality more often than women (X^2 = 14.04, p <.001).

Insert table 2 about here

Table 3 presents mean SDS scores as a function of performance group and sex. A 2 X 2 multivariate analysis of variance was performed between accurate and inaccurate groups and sexes with the six SDS scale scores entered as dependent variables. Results indicated a significant multivariate effect of performance group ($F = 3.28$, $p < .004$). Inspection of univariate tests of significance indicated that performance groups differed on the realistic ($F = 10.73$, $p < .001$), investigative ($F = 6.85$, $p < .01$) social ($F = 11.06$, $p < .001$) SDS scales. Accurate performers obtained significantly higher scores on the realistic and investigative scales than inaccurate performers, while inaccurate performers had higher social scores.

Insert table 3 about here

A multivariate effect of sex was also indicated ($F = 31.91$, $p < .001$). Men indicated stronger interests on the realistic ($F = 104.82$, $p < .001$), investigative ($F = 4.42$, $p < .04$), and enterprising ($F = 4.94$, $p < .03$) scales while women obtained higher scores on the artistic ($F = 10.11$, $p < .002$), and social scales ($F = 45.14$, $p < .001$). There was no performance group by sex interaction.

Finally, the association between interest classification and college major was tested. Subjects were grouped into one of the six interest categories based on their highest SDS scale scores. The SDS predicted subjects' college majors ($X^2 = 114.3$ $p < .001$), realistic and investigative classifications were associated with natural science and engineering majors, social classification with social science majors, artistic with language arts, and enterprising with business majors. The clerical classification was not associated with any particular major.

Discussion

Partitioning subjects by college major indicates that sex effects remain stable when previous academic experience is controlled for. However, significant differences between college majors for both sexes was indicated. This result suggests that academic experiences may effect task performance within and between sexes, but can not completely account for sex differences. There appears to be an additive relationship between sex and college major with men in the sciences performing most accurately and women in the arts performing the least accurately. This relationship has also been observed in tests of field-dependence, a construct often related to water-level task performance (DeRussy & Futch, 1971; Windsor, 1983).

The significant association between SDS classifications and college majors indicates that the results of experiment 2 provide validity data for the effects of college major on performance. Unfortunately, disproportionate cell sizes and underrepresentation of certain majors precluded a direct replication of experiment 1. It is worth noting that several samples of subjects were drawn in order to obtain the 25 female engineering majors in experiment 1. The total number of female engineers at the investigating university is 217 as compared to 1250 male engineers. There was, however, no problem obtaining male engineers and female social science majors.

The difficulty experienced in sampling females predicted to perform accurately calls attention to potential sampling biases that may occur in water-level experiments. A sample composed of predominantly female social science majors and male science/engineering majors may produce highly significant sex differences. However, if experiment 1 would have sampled the female engineering and the male social science majors, differences would have been mitigated, but not reversed. Indeed, no experiment has indicated a sex difference favoring females in water-level tasks (Halpern, 1986). One might speculate that psychology experiments drawing samples from introductory chemistry courses may produce surprising results.

It is of particular interest that the same interest factors indicated to be higher in subjects passing the task were higher in men and those associated with inaccurate performance were higher in women. One possible explanation of this result could have been the overlap between men and subjects performing accurately. However, there were nearly as many women performing accurately on the task as men and analyses controlled for disproportionate cell sizes due to the relatively small number of men performing inaccurately. It seems that the skills and interests reflected in SDS scores contribute to task performance.

Although the relationship between sex roles and water-level tasks has been discussed (Signorella & Jamison, 1978), measures of gender identity do not tap specific skills and interests related to performance. Preferences for traditionally masculine activities among subjects performing accurately on water-level tasks suggests some commonality between masculine typed experiences and water-level tasks. There are several potential explanations for this relationship, but such questions usually get casted into a discussion of the relative importance of biological and learning influences (Thomas & Jamison, 1981; Liben & Golbeck, 1986). The theoretical value of these interpretations is questionable. Alternative theoretical frameworks are needed to further understand the nature of the task upon which explanations of individual differences

can be built. There is also a need for longitudinal data in efforts to disentangle some of the identified factors contributing to water-level task performance.

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Table 1

Subjects Passing and Failing the Horizontality Task Within Each Sex by College Major Category n = 250

Sex	Business		Language Arts		Social Sciences		Natural Sciences		Engineering	
	Pass	Fail	Pass	Fail	Pass	Fail	Pass	Fail	Pass	Fail
Men	22	3	21	4	19	6	23	2	25	0
Women	11	14	11	14	6	19	15	10	18	7
Total	33	17	32	18	25	25	38	12	43	7

Table 2
Performance Groups as a Function of Subject Sex n = 194

	Accurate	Inaccurate	
Men	69	28	97
Women	36	61	97
Total	105	89	

Table 3

Mean SDS Scores as a Function of Performance Group and Subject Sex

	Men		Women	
	Accurate	Inaccurate	Accurate	Inaccurate
Realistic	26.7	21.2	12.9	10.7
Investigative	25.9	23.1	22.8	21
Artistic	20.1	21.1	25.3	25.9
Social	24.4	24.4	31.7	34.6
Enterprising	29.1	33.9	27.3	29.3
Conventional	21	23.3	22.8	22.8